

Amendments to the Claims:

1 **1. (currently amended)** A method for controlling the temperature of a mass cooled by a
2 free piston cryocooler, the method comprising:

3 (a) for output cooling power demands requiring a piston stroke exceeding a selected
4 minimum piston stroke, controlling the output cooling power of the cryocooler by
5 modulating piston stroke as an increasing function of the difference between
6 sensed mass temperature and a command reference input temperature; and

7 (b) for output cooling power demands requiring a piston stroke less than the selected
8 minimum piston stroke, maintaining the piston stroke at substantially the selected
9 minimum piston stroke and applying thermal energy to the mass.

1 **2. (original)** A method in accordance with claim 1, wherein the selected minimum piston
2 stroke is the minimum piston stroke necessary to maintain gas bearing lubrication of the
3 cryocooler.

1 **3. (original)** A method in accordance with claim 2, wherein, for output cooling power
2 demands requiring a piston stroke less than the selected minimum piston stroke, the
3 thermal energy is applied as an increasing function of the difference between the cooling
4 power applied to the mass by the cryocooler at the selected minimum piston stroke and
5 the cooling power demand.

1 4. **(original)** A method in accordance with claim 3, wherein, for nominal design
2 operation, the output cooling power demand is greater than the output cooling power at
3 the selected minimum piston stroke and is nearer the output cooling power at the selected
4 minimum piston stroke than it is to the cooling power at a maximum permissible piston
5 stroke.

1 5. **(currently amended)** A method for controlling the temperature of a mass cooled by a
2 free piston cryocooler, the cryocooler having a piston and a closed loop control system,
3 the control system deriving a piston drive signal from the difference between a set point
4 signal and a fed back temperature signal representing the temperature of the mass, the
5 method comprising:

6 (a) for piston drive signals corresponding to piston strokes exceeding a selected
7 minimum piston stroke, controlling the output cooling power of the cryocooler by
8 the piston drive signal;

9 (b) for piston drive signals corresponding to piston strokes less than the minimum
10 piston stroke, maintaining the piston stroke at substantially the minimum piston
11 stroke; and

12 (c) for piston drive signals corresponding to piston strokes less than the minimum
13 piston stroke, applying thermal energy to the mass as an increasing function of the
14 difference between the piston drive signal for the minimum piston stroke and the
15 applied piston drive signal.

1 6. **(original)** A method in accordance with claim 5, wherein the selected minimum piston
2 stroke is at the piston stroke necessary to maintain gas bearing lubrication of the
3 cryocooler.

1 7. **(currently amended)** An improved, temperature controlled, free piston cryocooler
2 including a free piston driven in reciprocation by a prime mover having a modulatable
3 stroke, the cryocooler including a cold end and a warm end and being capable of
4 transporting heat away from a thermal mass providing a thermal load and positioned at
5 the cold end, the cryocooler having a feedback control system including (i) a temperature
6 command input for inputting a reference signal representing a desired cold end
7 temperature of the thermal mass load, (ii) a feedback loop including a temperature sensor
8 at the cold end for generating a signal representing actual cold end temperature, and (iii) a
9 summing junction for generating an actuating signal representing the difference between
10 the desired temperature and the actual temperature of the cold end, the improvement
11 comprising the combination of:

12 (a) a piston stroke modulator connected to receive the actuating signal and for
13 converting the actuating signal to a piston drive signal representing a desired
14 piston stroke, the modulator connected to the prime mover for controlling the
15 prime mover its stroke when the desired piston stroke exceeds a selected

16 minimum stroke and maintaining the minimum stroke when the desired piston
17 stroke is less than the minimum stroke; and
18 (b) a heating apparatus including a heater in thermal connection to the cold end and a
19 heater control element having an input connected to receive the piston drive signal
20 for modulating the heater power as an increasing function of the difference
21 between the desired piston stroke and the minimum piston stroke when the
22 desired piston stroke is less than the minimum piston stroke.

1 8. **(currently amended)** An improved closed loop control system for controlling a free
2 piston cryocooler having a heat pump including a piston, the control system controlling
3 the temperature of a mass being cooled by the cryocooler and including (i) a dynamic leg,
4 (ii) a reference input for inputting a desired, set point temperature and (iii) a feedback leg
5 including a temperature sensor in thermally conductive connection to the mass being
6 cooled, for comparison of a signal from the temperature sensor to the reference input to
7 provide a first an actuating signal, the improvement comprising:

8 (a) a first branch of the dynamic leg for controlling the piston amplitude of
9 oscillation comprising:
10 (i) a first controlled element including the prime mover and the heat pump
11 ~~and controlling the piston amplitude of oscillation;~~ and
12 (ii) a first control element having an output connected to an input of the
13 first controlled element and an input to which a first the actuating signal is

14 applied for controlling the piston amplitude of oscillation, the first control
15 element including ~~a an-actuating-signal~~ limiter for maintaining the output
16 of the first control element greater than a selected piston limit value
17 substantially corresponding to a minimum piston stroke; and

18 (b) a second, parallel branch of the dynamic leg comprising:

19 (i) a second controlled element including a heater in thermally conductive
20 connection to the mass; and

21 (ii) a second control element having an output connected to an input of the
22 second controlled element and an input to which a second ~~an~~ actuating
23 signal is applied for controlling the heating power output of the heater, the
24 second actuating signal being the same as or derived from the first
25 actuating signal, the second control element, for a second ~~an~~ actuating
26 signal value exceeding the selected piston limit value, applying
27 substantially no heating power and, for a second ~~an~~ actuating signal value
28 less than the selected piston limit value, applying increasing heating power
29 as a function of decreasing second actuating signal value.

1 9. (original) A control system in accordance with claim 8 wherein the control elements
2 comprise a digital microprocessor and associated storage forming a programmed
3 computer system having control instructions and algorithms stored in the storage.